Appendix L

Nonoperational Area Evaluation

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Terms

BCCA	BC Control Area
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
DU	decision unit
EPA	U.S. Environmental Protection Agency
FS	feasibility study
GIS	geographical information system
GPS	global positioning system
LiDAR	Light Detection and Ranging
NP	nonoperational property
NPE	nonoperational property evaluation
OSE	Orphan Sites Evaluation
OU	operable unit
RARA	Radiation Area Remedial Action
RCCC	River Corridor Completion Contract
RI	remedial investigation
ROD	record of decision
SESP	Surface Environmental Surveillance Program
UPR	unplanned release
WIDS	Waste Information Data System

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L1 Introduction

This appendix presents information that supports the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation (RI)/feasibility study (FS) conducted for 100-BC (DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC Operable Unit*). Most of the waste sites in 100-BC are located close to former industrial facilities. There are large land areas (beyond the industrial areas and their associated facilities and waste sites) that have little or no subsurface infrastructure or indication of past or present releases of hazardous constituents. This land is referred to as nonoperational property (NP). This appendix presents the nonoperational property evaluation (NPE) specific to100-BC.

L1.1 Scope of the Nonoperational Property Evaluation

This NPE is not directly part of the CERCLA RI/FS process, in that it has no role in determining the basis for remedial action or in evaluating remedial alternatives for contaminated soils or groundwater. 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," requires that the nature and extent of contamination be evaluated and appropriate remedial actions taken. Two important outputs from the NPE are evidence that effort has been taken to identify where waste may be present outside of operational areas and, where appropriate, the inclusion of NPE waste sites that may warrant further consideration as part of the RI/FS. The NPE also documents nonoperational conditions for use in risk communication and stakeholder information.

There are fate and transport mechanisms that could potentially distribute contaminants to nonoperational areas. The most credible are human disposal, wind-blown dust dispersion, air emissions from stacks during active operations, overland flow, and biological vectors (intrusion by plants and animals). Multiple lines of evidence have been developed to assess these fate and transport mechanisms and the potential for contamination to exist outside known operational areas. The following areas of focus were used in developing the lines of evidence:

- **Review of existing programs, data, and information with a nonoperational area focus:** Decades of environmental monitoring and surveillance have been conducted and reported at the Hanford Site. In addition to general (routine) monitoring that has included nonoperational areas, special studies have been commissioned and conducted that assess broad-area evidence of emissions and releases from facilities and waste sites.

- **Results of Orphan Sites Evaluations:** The Orphan Sites Evaluation (OSE) is a program that has been designed primarily to support cleanup and long-term stewardship activities in the River Corridor. It provides a detailed understanding of disturbed areas (contaminated or not). Review of historical records and imagery, combined with on-the-ground walk-downs and field investigations, provide a comprehensive evaluation of current conditions in nonoperational areas.

- **Statistical analyses:** Two statistical analyses were conducted as adjuncts to environmental monitoring, data review, and field investigations. The first was developed and applied to enhance efforts to systematically and rigorously locate potential waste disposal sites. The second evaluated radionuclide distribution (based on available soil concentration data and aerial radiological surveys) in order to quantify and understand relationships with known waste sites and examine the potential for unidentified sites to exist outside operational areas.

L1.2 100-BC Description

The 100-BC Area is located in the northern portion of the Hanford Site adjacent to the Columbia River. It covers more than 11.54 km^2 (4.45 mi^2) of land along the southern shore of the Columbia River and includes the 100-BC-1 and 100-BC-2 Source Operable Units (OUs), the 100-BC-5 groundwater OU, and the nonoperational area. The 100-BC-1 OU contains waste sites associated with the original facilities constructed to support the B Reactor operations, as well as the cooling water retention basin systems for both the B and C reactors. The 100-BC-2 OU contains waste sites associated with the facilities to support the C Reactor operations and other waste sites at 100-BC, including most of the solid waste burial grounds. The source OUs include contamination associated with liquid, solid, and unplanned release (UPR) waste sites. The 100-BC-5 Groundwater OU comprises the groundwater at 100-BC affected by contaminant releases from the source OUs.

Surface elevations in this region are relatively flat. The riverbank slopes steeply (10:1 grade) to the river shoreline. Significant topographic features near 100-BC include Gable Butte to the south, as well as an extensive gravel beach that is exposed along the Columbia River during periods of low river stage. On the upstream end of the area, the bank is less steep and broadens into a gently sloping shoreline (50:1 grade) that is approximately 150 m (492 ft) wide (DOE/RL-2010-96).

The land adjacent to the B and C Reactors that was once farmed has developed into dense stands of cheatgrass and Sandberg's bluegrass, which have excluded the establishment of shrubs. The natural soils in this area were shallow (15 to 31 cm [6 to 12 in.]) silt loam over river-deposited gravel. The reactor construction activities disturbed the natural soil strata, leaving a surface of sandy gravel and cobbles in the heavily disturbed areas surrounding the facilities. This alteration in soil structure resulted in a change in the plant communities that became established. The sandy-gravel soils tend to favor the native plants, and cheatgrass is not as dominant in these heavily disturbed areas as in the fine-grained soils.

Areas that were no longer used for construction activities or operations have revegetated naturally to communities dominated by gray rabbitbrush, with an understory of Sandberg's bluegrass, bulbous bluegrass (*Poa bulbosa*), and cheatgrass. Sagebrush is present but infrequent. Most operation areas, including unremediated wastes sites, are maintained free of vegetation for contamination control, fire prevention, and housekeeping purposes. The only vegetation that occurs in the areas that were not revegetated is very sparse and consists of early successional species such as cheatgrass, Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and bur ragweed (*Ambrosia acanthicarpa*).

Less disturbed portions of the Hanford Site to the southeast of 100-BC are typified by shrub-steppe habitat, consisting of a native shrub canopy and a grass/herbaceous understory. Native shrubs include sagebrush, gray rabbitbrush, and spiny hopsage (*Grayia spinosa*). Understory species typically include herbaceous forbs, native perennials such as yarrow (*Achillea millefolium*) and buckwheat (*Eriogonum spp.*), and perennial grasses such as Sandberg's bluegrass, bulbous bluegrass, Indian ricegrass (*Oryzopsis hymenoides*), needle-and-thread grass (*Stipa comata*), and sand dropseed (*Sporobolus cryptandrus*). Cheatgrass is also prevalent throughout these less-disturbed areas surrounding 100-BC (DOE/RL-2005-40, *100-B/C Pilot Project Risk Assessment Report*).

L2 Nonoperational Property Evaluation Approach

River Corridor cleanup efforts have focused on known waste sites located within operational areas (often within perimeter fences) and on a limited number of known sites outside these boundaries. Where surveillance monitoring or focused investigative activities have identified previously unknown sites, they have been identified and evaluated for inclusion within the scope of the cleanup efforts. Operational areas comprise a small fraction of the total land surface in the River Corridor. Outside of the operational areas is the NP area. For purposes of this appendix, the NP area in the River Corridor is defined as that area beyond the boundaries of waste sites listed in the Waste Information Data System (WIDS) database. The NP area is considered not to be directly associated with a Hanford Site process or operational activity known or suspected to contribute CERCLA hazardous constituents to the environment.

The approach to the NPE for the River Corridor is to develop a conceptual model of the fate and transport mechanisms that could distribute contaminants from Hanford operations that would warrant further evaluation in the nonoperational areas, and then apply multiple lines of evidence to examine the likelihood that such contamination is present. The lines of evidence include results from long-term surveillance and monitoring programs and other studies; results from a spatial model for predicting the location of man-made features (including waste sites) based on proximity to man-made and topographic features; a spatial model for predicting where elevated radionuclide concentrations (specifically cesium-137) are present in soil based on aerial radiological survey results; and results from the OSE program.

Section L2.1 presents a brief description of potentially significant contaminant fate and transport pathways. Summary descriptions of the key surveillance and monitoring programs and other studies for the nonoperational area in the 100-BC Area are presented in Section L2.2. Brief descriptions of the statistical analyses are presented in Section L2.3. A brief description of the OSE program is presented in Section L2.4.

L2.1 Nonoperational Contaminant Transport Pathways

The NP area, having no history of releases of hazardous or radioactive substances, is presumed to have a low likelihood of contamination that would require a response action under CERCLA. The principal objective of this evaluation is to examine multiple lines of evidence to confirm that hazardous or radioactive substance releases are not present in the NP area. An outcome of this evaluation could be the identification of areas where releases, or contaminant transport, may have occurred.

The following is a select set of contaminant release pathways that apply when evaluating the potential for contaminant transport into nonoperational areas:

- **Anthropogenic contaminant sources.** Contaminants from facilities or known waste sites may have been physically transported by human actions to shallow soils outside of waste site boundaries. Several activities and programs at the Hanford Site identify waste sites that have resulted from these types of activities. Section L2.2 presents an overview of these activities and programs.

- **Transport via wind-blown dust.** Hazardous and radioactive substances in surface soils and materials can become suspended into the air, dispersed to downwind locations, and subsequently deposited onto the ground. Approximately 6 percent of the 1,518 km^2 (586 mi^2) Hanford Site (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or used. Potential fugitive dust emission sources are located in the five operations areas within this actively disturbed area: 100 Area, 200 East, 200 West, 300 Area, and 400 Area. The potential for fugitive dust emissions from these sources is generally conceived to occur subsequent to disturbance, erosion, or removal of soil covers over waste sites or through plant or animal biointrusion. These events can expose erodible material that contains contamination. Engineering controls (e.g., surface soil stabilization, dust suppression water, or work cessation due to wind conditions) can be, and are, applied to mitigate or eliminate this transport pathway. However, contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas could contain erodible material that might produce fugitive emissions from resuspension of windblown dust (DOE/RL-2010-17, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009*). Figure L-1 depicts a conceptual model of windblown dust transport.

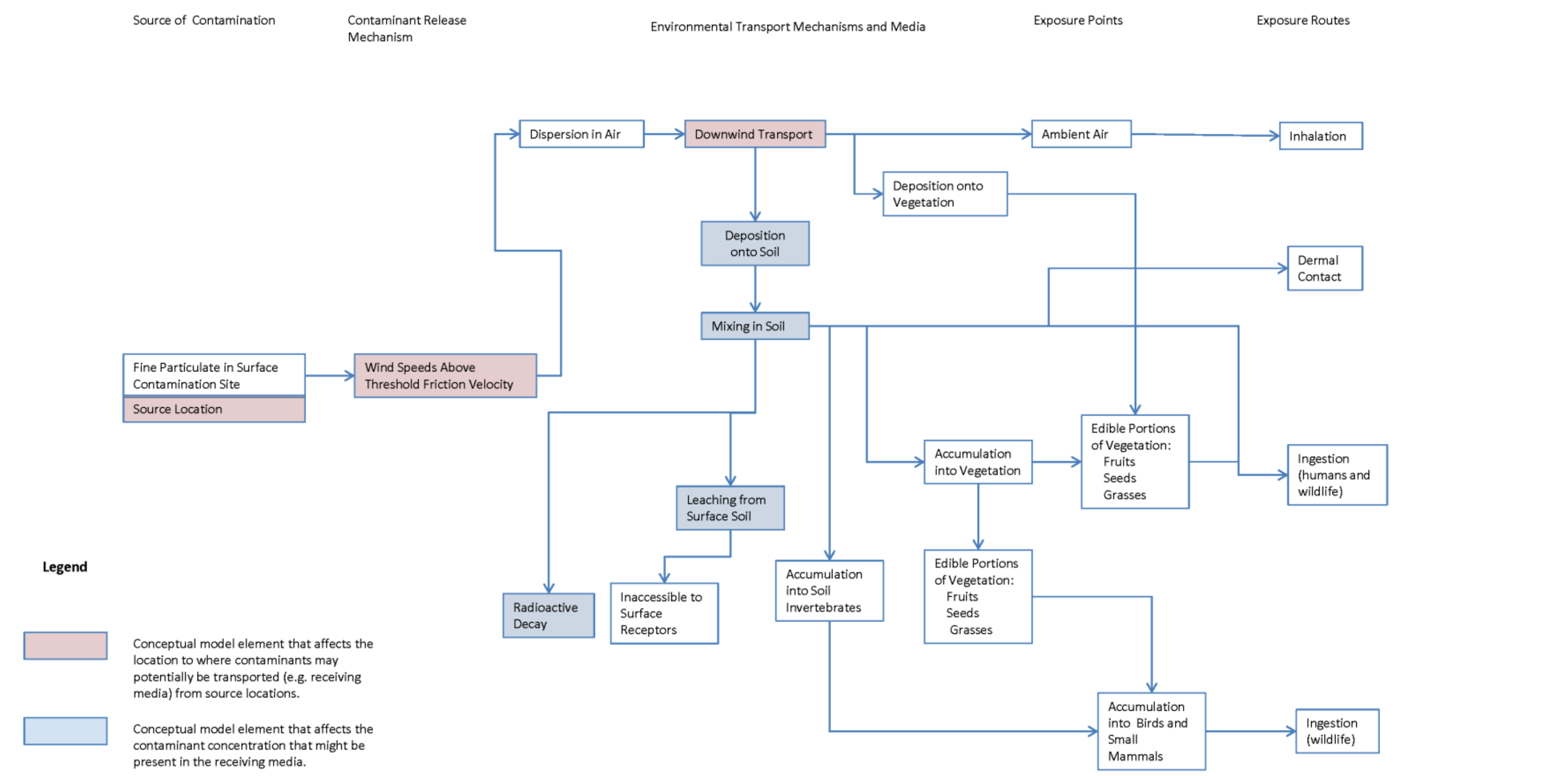

Figure 2-1. Non-Operational Area Conceptual Model of Contaminant Fate and Transport Pathways – Transport of Windblown Dust

Figure L-1. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport of Windblown Dust

- **Emissions from facility stacks.** Hazardous and radioactive substances emitted into the air from former and currently operating facility stacks and vents can be dispersed to downwind locations and subsequently deposited onto the ground. Three groups of sources of Hanford Site stack air emissions had the potential to impact the River Corridor by air deposition. Two of the groups, which represent by far the greatest potential contributors, are stack emissions that occurred during active operations between 1944 and 1972. The two groups are examined separately based on their physical location and type of contamination. Group one is stack emissions from 200 Area operations that separated plutonium and uranium from irradiated reactor fuel. The second group is stacks in the 100 Area that exhausted ventilation air from the working areas of the nine production reactor facilities. The 100 Area sources were minor emissions compared with those from 200 Area facilities. The third group is nonradionuclide emissions resulting from coal-fired power plants used to generate steam for heating and process operations. There were large two power plants in the 200 Area that operated until the mid-1990s: 284-E Power Plant in the 200 East Area, and 284-W Power Plant in the 200 West Area (WHC-EP-0472, *Facility Effluent Monitoring Plan for the 284-E and 284-W Power Plants*). Nonradionuclide toxic air pollutants that could be emitted from coal-fired power plants are principally trace metals, but also include traces of volatile organic compounds such as formaldehyde, and polycyclic organic matter. The polycyclic aromatic organic matter and certain trace metals, in particular arsenic, cadmium, lead, and antimony, adhere to the fine particulate matter emitted from a power plant stack. Figure L-2 presents the conceptual model of transport from stack emissions.

- **Overland transport.** Hazardous and radioactive substances in surface materials can be transported away from facilities or known waste sites by surface runoff (overland flow). This could conceivably occur following precipitation events or, as has been documented, from releases (or “spillage”) of process liquid waste that had been discharged to liquid waste disposal sites. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site. Factors that affect overland flow include slope of the ground surface, soil texture, vegetative cover, and frequency of precipitation.

  The Hanford Site sits in a semiarid region where precipitation is more than balanced by evaporation and transpiration such that substantial overland flow from precipitation is an unlikely occurrence. A more likely source for overland flow is spills or releases from liquid waste disposal facilities during historical active operations. In general, these leaks were infrequent and documented through written and photographic records. Most resulted in localized contamination in and around the disposal sites. A number of these sites have been remediated under the interim action records of decision (RODs).

- **Biointrusion.** Hazardous and radioactive substances in shallow soil can be transported to plants at ground surface through their roots, or disturbed and transported to the soil surface by burrowing animals or insects. Plants extend roots into the soil to extract nutrients and water. Most of the mass of plant roots is concentrated within the shallow soil; however, some deep-rooted plant species are found at the Hanford Site. Unless actively managed and controlled, deep-rooted vegetation (e.g., tumbleweeds, sagebrush) growing over underground sources of contamination may selectively uptake contaminants, particularly radionuclides, into their tissues. When radionuclides are transported from roots to aerial portions of the plant, surface contamination may result. Desert animals and insects burrow for shelter from the heat, cold, or predators; reproduction; feeding; and water conservation. Most wildlife burrow no more than a few feet in depth; however, some macroinvertebrates (harvester ants) have been reported to burrow to depths of up to 2.4 m (8 ft) in soil at the Hanford Site. Animals that burrow into contaminated soils could unearth contaminants and disperse them on the soil surface. The conceptual model of biointrusion is depicted in Figures L-3 and L-4.

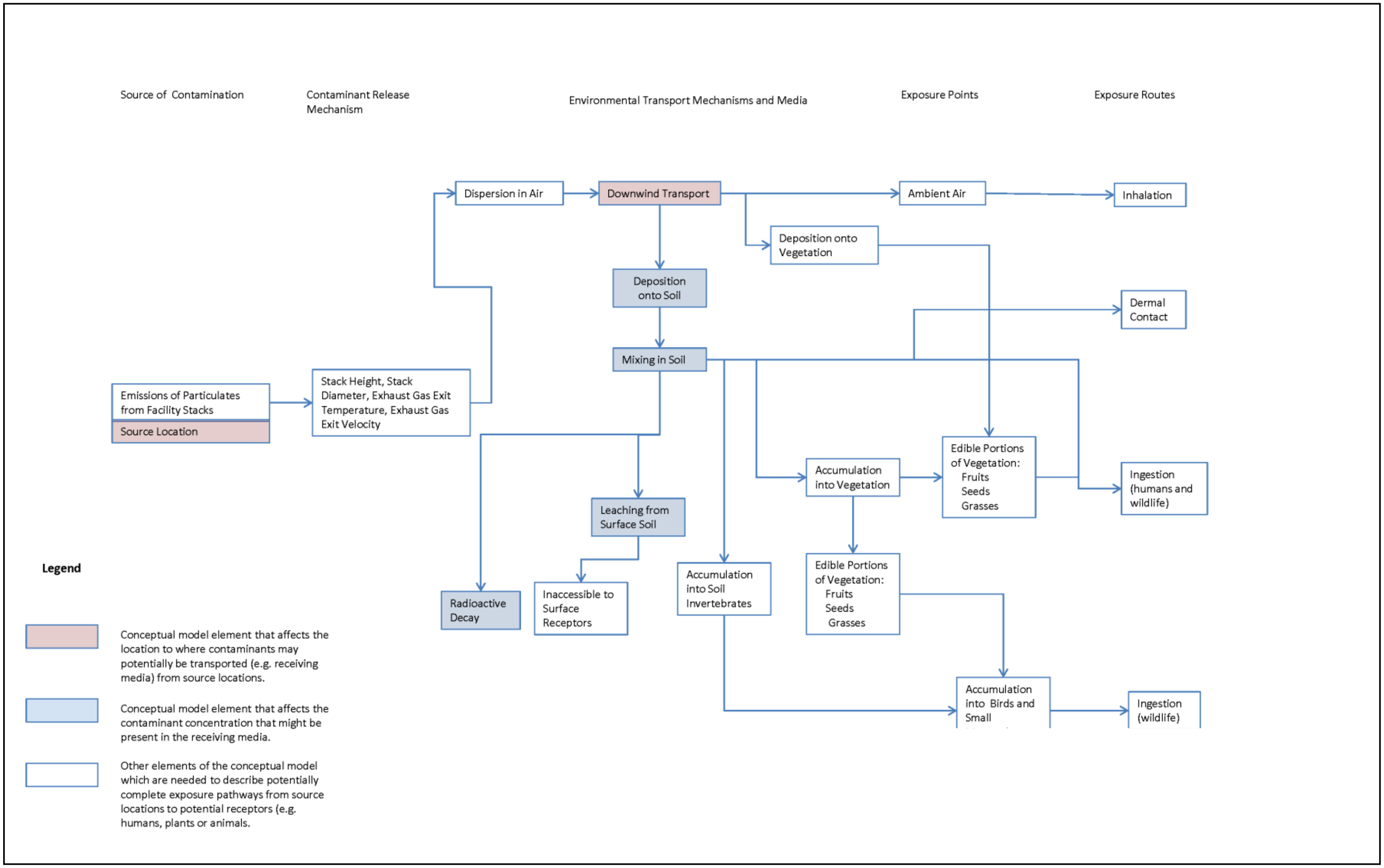

Figure L-2. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Emissions from Facility Stacks

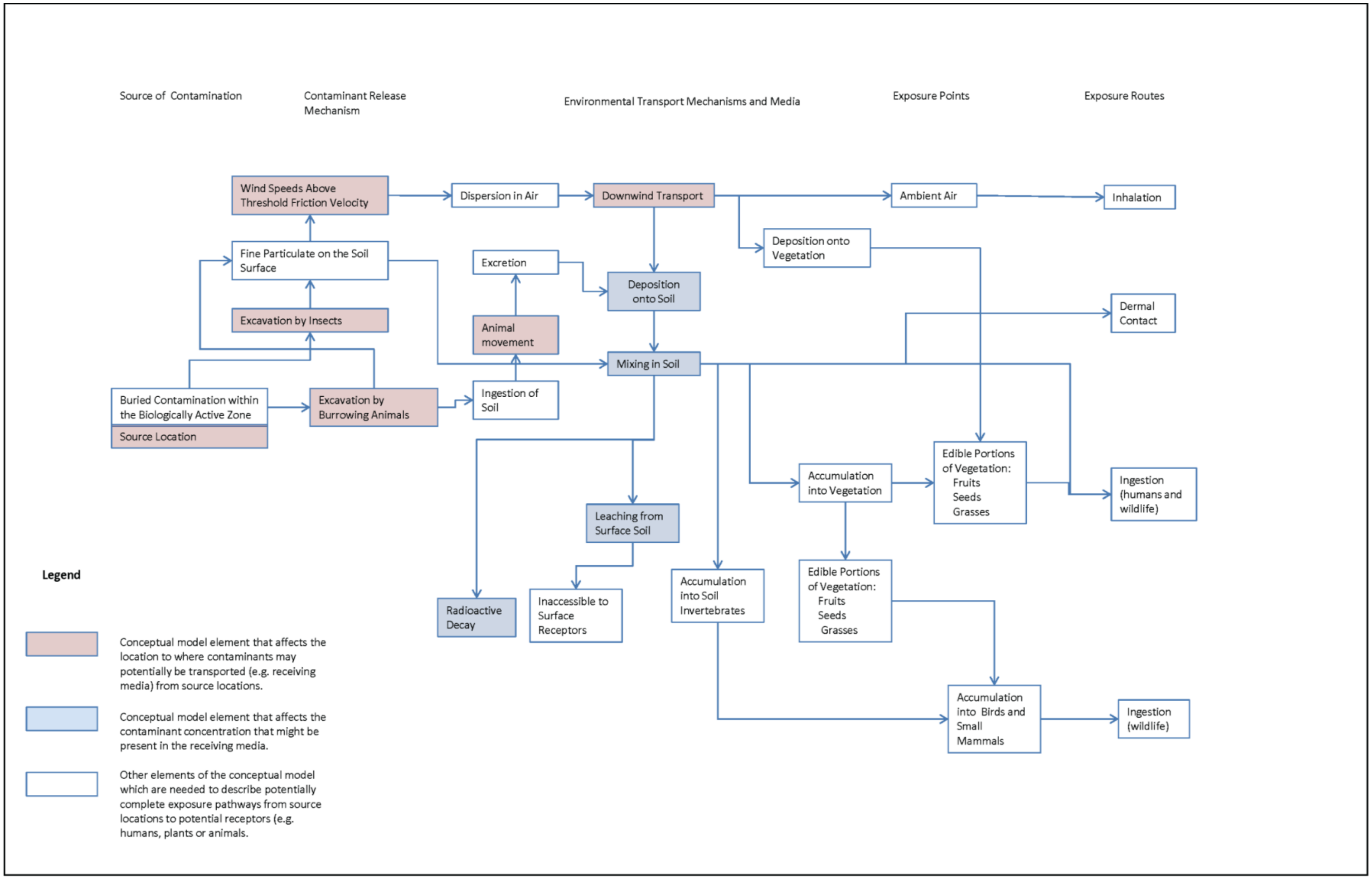

Figure L-3. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Animal Intrusion of Buried Contaminants

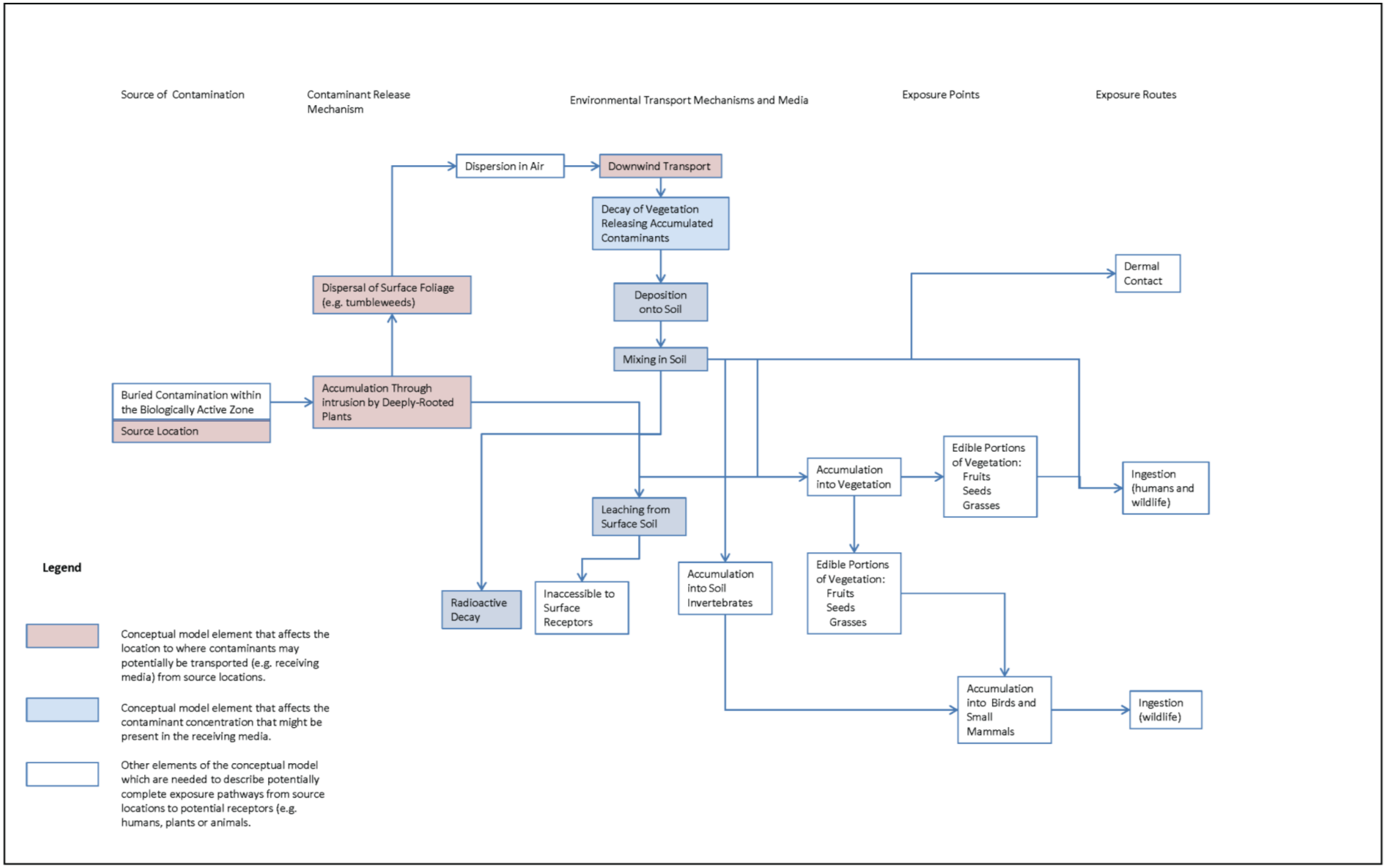

Figure L-4. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Intrusion of Deep-Rooted Plants

L2.2 Surveillance and Monitoring Programs

Several programs at the Hanford Site collect environmental surveillance and monitoring data. Many of these programs collect data to address regulatory requirements for emissions, effluent discharges, or U.S. Department of Energy (DOE) orders regarding radiological control. Other programs perform environmental monitoring of soil, water, air, or vegetation. Most of these programs are summarized in the annual environmental report for the Hanford Site (e.g., DOE/RL-2014-52, *Hanford Site Environmental Report for Calendar Year 2014*).

Fifteen Hanford Site programs that identify waste sites and/or collect environmental monitoring and surveillance data are listed in Table L-1. In addition, Table L-1 identifies five other sources of information and data applicable to a nonoperational area evaluation. Information and data from these programs were evaluated to identify trends in how hazardous substances or radionuclides may have been transported from operational areas or waste sites to nonoperational areas within the River Corridor. Information from the programs involved with soil, air, or vegetation monitoring, or with radiological control, were of most use in the NPE. The evaluation of the results from these programs as they pertain to the 100-BC Area is summarized in Section L3.1.

Table L-1. Existing Hanford Site Programs Related to Environmental Data and Monitoring

Ongoing Hanford Site Programs	
Air Emissions Monitoring	Liquid Effluent Monitoring
Ambient Air Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Ambient Air Monitoring
Soil Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Soil Monitoring
Vegetation Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Vegetation Monitoring
Radiological Dose Measurement Near Hanford Site Facilities and Operations	Radiological Surface Surveys Near Hanford Site Facilities and Operations
Groundwater Monitoring	Radiation Area Remedial Action Project
Waste Information Data System	Spill and Release Reporting
Vegetation Control Activities	
Additional Information and Data Sources	
Aerial Radiological Surveys	*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* (DOE/RL-2007-21, Rev. 0)
Aerial Photography (Includes Light Detection and Ranging)	Emissions estimation and dose assessments conducted as part of the Hanford Environmental Dose Reconstruction Project
Hanford Site Background Studies	

L2.3 Statistical Analyses

The statistical analyses focused on the following tasks:

- Developing and applying a predictive model for waste site locations
- Establishing association between cesium-137 measured directly in soil and high resolution aerial survey results
- Developing a sitewide model of soil cesium-137 using lower resolution sitewide aerial surveys

The results of these analyses were used to model the likelihood of finding previously undiscovered waste sites in the nonoperational areas as a function of man-made and topographic features, and to model the potential for radionuclide concentrations (specifically cesium-137) in surface soil to be higher than selected threshold concentrations.

The following subsections describe these lines of investigation. Section L3.2 discusses the results from these analyses.

L2.3.1 Predictive Modeling of Waste Site Locations

The predictive model is based on the conceptual model that waste sites are located in proximity to anthropogenic features such as roads or existing operational areas, or flat or low-lying topography. The distributions of these geographic variables, measured at WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A quantitative model was developed to show the probability of a waste site being located at any unsampled location within the Hanford Site as a function of these geographic measures. Factors considered in developing geographic variables for known waste sites and sources included distance to operational areas; distance to roads, railroad grades, and utility rights of way (e.g., power lines); and topography, including slope aspect elevation, and curvature. These models were used to rank areas based on the relative probability that a previously undiscovered waste site might exist.

L2.3.2 Aerial Surveys and Soil Radionuclides

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive aerial radiological surveys. Soil measurements were expressed as activities per unit mass (pCi/g), suitable for estimation of exposure for risk assessment, whereas data obtained from aerial surveys were expressed as gross counts for gamma-emitting radionuclides. Aerial survey data could be used to estimate exposure if it could be calibrated with soil cesium-137 activity data. Predictive models and maps of the probability that cesium-137 levels would be expected to exceed screening levels could be prepared based on the statistical relationship between soil activity measurements and aerial survey gross counts.

A detailed investigation in the BC Control Area (BCCA), which included collecting high-resolution aerial survey data and relatively high-density soil sampling, provided data to perform a detailed geostatistical analysis. The analysis of the BCCA data supported development of a sitewide model based on less resolved, but more laterally extensive, aerial surveys of the whole Hanford Site. The results of the site-wide model were used to draw conclusions specific to the River Corridor. The results of both analyses support the utility of aerial radiological surveys for estimating concentrations in soil for unsampled areas.

L2.4 Orphan Sites Evaluation

The OSE is a systematic approach to evaluate land parcels in the River Corridor to ensure that all waste sites or releases requiring characterization and cleanup have been identified. Information collected through these evaluations also supports elements of the CERCLA Section 120(h)(4), "Federal Property Real Disposal Process," requirements for review and identification of uncontaminated property at federal facilities. The OSE supplemented past systematic efforts that identified source waste sites, including the Tri-Party Agreement management procedures (TPA MP-14) (RL-TPA-90-0001, *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)") discovery process for identifying known and potential waste sites and the CERCLA hazard ranking conducted in 1985 and 1986 to place the Hanford Site on the National Priorities List (NPL) (40 CFR 300, Appendix B, "National Priorities List").

Two of the key elements of an OSE include a historical review and a field investigation. Review of historical information was conducted to identify potential orphan sites and to target areas for further evaluation during the course of conducting the associated field investigation. Historical research focused on identifying specific items or features typically associated with a waste site. The most common features associated with a waste site in reactor areas include drains, cribs, drywells/French drains, burial grounds, pipelines, aboveground and belowground storage tanks, septic systems, drain fields, burn pits, trenches, ditches, pits, spills, sumps, vaults, ash pits, disposal areas, pumps, and buildings and facilities that contain chemicals and radiological contaminants. Information obtained and used in the historical review included the following resource types:

- Maps
- Construction and operations drawings
- Technical and operations documents
- Construction and operations photographs
- Aerial photographs
- Geophysical survey results
- Cleanup verification packages
- Sampling logbooks
- Personnel interviews

Field investigation activities were used to provide another level of assurance by conducting systematic walking surveys to document potential orphan sites and to follow up on potential orphan sites identified from historical review. Three primary tools provided the media to record the information observed in the field: hand-held Trimble GeoXT™ global positioning system (GPS) units, digital cameras, and field logbooks. Geophysical survey instrumentation was used to supplement these tools in selected areas of suspect subsurface features identified during the historical review or field investigation.

To achieve a systematic approach for area coverage, standardized 30 × 30 m (100 × 100 ft) conceptual grids were established over the investigation areas. The grid and existing known features in the areas were loaded onto the GeoXT GPS units, which were used in the field to monitor progress and record information. Walking surveys were typically performed in pairs with approximately 15 m (50 ft) spacing

™Trimble GeoXT is a trademarked product of Trimble Navigation Limited, Sunnyvale, California.

between individuals. Features encountered during this investigation were recorded using the GPS unit, digital camera, and field logbook.

The field investigation for regions of the River Corridor used a graded approach. High resolution, four-band (red, green, blue, and near-infrared) orthophotography imagery and Light Detection and Ranging (LiDAR) topography data were collected for approximately 57,468 ha (142,000 ac) of the River Corridor in April 2008. The data were collected in the early spring when foliage and undergrowth obscuring the ground surface was at a minimum. The orthophotography and LiDAR data were used to conduct "virtual walkdowns" of the areas. Based on results of these "virtual walkdowns," areas were selected to conduct walking surveys (30 × 30 m [100 × 100 ft] reference grid system). Vehicle surveys along accessible roads and utility easements were also part of the field investigation. In addition, standard walking surveys were conducted throughout the River Corridor along the Columbia River, based on the level of interest in the shoreline area and its inclusion as part of the Hanford Reach National Monument (65 FR 37253, "Establishment of the Hanford Reach National Monument").

L3 Evaluation Results

This section summarizes the results of the NPE in 100-BC of the River Corridor based on the approach presented in Section L2. The NPE is based on multiple lines of evidence, including the results from surveillance and monitoring programs, and other studies conducted in the River Corridor; the results from statistical analyses performed to identify the potential presence of waste sites and to evaluate the spatial distribution of selected radionuclides in soil; and the results from the OSE.

L3.1 Results from Surveillance and Monitoring Programs

Hanford Site programs, which provided information characterizing conditions in the nonoperational areas in and around 100-BC, included the soil, air, and vegetation sampling conducted as part of the Near Facility Monitoring program and the Surface Environmental Surveillance Program (SESP). The radiological control program emphasized radiological surveys and activities for identifying and controlling biological vectors (biointrusion from plants and animals), and external radiation monitoring conducted as part of the SESP.

Other activities that contribute to characterizing conditions in the nonoperational areas include the waste site discovery process under TPA MP-14, which results in identified waste sites being inventoried in WIDS and, as discussed in Section L3.3, the OSE. Historically, interim actions conducted under the Radiation Area Remedial Action (RARA) project contributed to stabilizing and controlling releases from waste sites. The results from these programs have been discussed using the framework of the conceptual model described in Section L2.1.

L3.1.1 Anthropogenic Disposal Activities

Past and present investigation activities provide confidence that waste site locations within the River Corridor are known. Waste site identification activities in the River Corridor fall into two categories: systematic and observational. Various systematic programs have been conducted at different times since the beginning of the Hanford Site transition from production to cleanup in the 1980s, with the most recent being the OSE program that was initiated in 2004. An inventory of known and potential waste sites has been maintained in the WIDS database since the early 1980s, and is continually maintained through the TPA MP-14 discovery process. Between 1985 and 1988, preliminary assessment/site inspection activities were completed to identify waste sites and prioritize the relative hazards. Waste disposal information was collected through exhaustive reviews of literature and maps, employee interviews, and visual inspection of all sites and UPRs. Results were organized and sites were ranked with respect to potential environmental impacts in accordance with a slightly modified version of the CERCLA hazard ranking system. The results from this process provided information to support addition of the 100 and 300 Areas to the NPL (40 CFR 300, Appendix B) and subsequent listing of waste sites in Appendix C of Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*.

A variety of characterization activities conducted as part of the RI/FS process has further characterized potential release and disposal activities in the 100 Area. These historical activities are summarized in DOE/RL-2008-46-ADD3, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*.

L3.1.2 Wind-blown Dust Emissions

Emission sources, which could release contaminants through wind-blown dust, are described variously as "fugitive," "diffuse," or "nonpoint" emissions sources (DOE/RL-2010-17). The Hanford Site consists of 1,518 km^2 (586 mi^2) of semiarid shrub-steppe land, of which approximately 6 percent (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or actively used. This 6 percent of land is distributed into large operational and support areas where almost all fugitive emissions sources are located: 100, 200 (which includes 200 East and 200 West), 300, and 400 Areas.

The potential for fugitive dust emissions from waste sites (prior to their cleanup) is generally characterized as occurring subsequent to erosion of soil covers or plant or animal biointrusion, which may expose erodible material containing concentrations of radionuclides. Contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas also could contain erodible material that is radiologically contaminated, and that could produce fugitive emissions from resuspension of wind-blown dust (DOE/RL-2010-17).

The RARA program is responsible for the interim stabilization, surveillance, and maintenance of the inactive waste sites at the Hanford Site. Interim stabilization measures to control fugitive dust have historically been performed on inactive waste sites prior to their cleanup. Stabilization measures included consolidation of surface contamination within the waste site from which it originated, then covering the waste with a layer of soil or other material (such as cobbles). Waste sites were then revegetated or treated as needed with a nonselective herbicide. Quarterly surveillance, annual radiological surveys, annual herbicide applications, removal of deep-rooted vegetation, and occasional corrective action for small areas of surface contamination continued following stabilization. Interim stabilization reduced sources of wind-blown dust potentially originating from contaminated soils.

The potential magnitude of wind-blown dust transport can be evaluated from the frequency of restrictions to visibility and ambient air monitoring for particulate matter and radionuclides in air. Dust, blowing dust, and smoke from field burning are described as phenomena causing restrictions to visibility (that is, visibility less than or equal to 9.6 kg [6 mi]). Reportedly, there are few such days at Hanford (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*). Particulate air monitoring shows that annual average PM_{10} (particulate matter finer than 10 micrometers [µm] in diameter) concentrations at the Hanford Meteorological Station are similar to PM_{10} concentrations at the Benton Clean Air Agency station located in Kennewick.

L3.1.3 Stack Emissions

Radionuclide emissions formerly produced from stacks in the 200 Area and the 100 Area had the potential to affect the River Corridor through deposition from the air. Based on studies conducted as part of the Hanford Environmental Dose Reconstruction Project, most of the emissions occurred between 1944 and 1972 from facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel (PNWD-2222 HEDR, *Radionuclide Releases to the Atmosphere from Hanford Operations*). The largest releases from these facilities occurred in 1945, before effective filtering devices were installed ahead of the stacks to prevent the discharge of volatile and particulate radionuclides. Most of the inventory emitted consisted of gaseous and/or short-lived radionuclides, which would be unlikely to result in measurable concentrations in soil in Hanford Site nonoperational areas. The nine production nuclear reactors in the 100 Area had stacks to exhaust ventilation air from the working areas of the reactor facilities. These were minor sources of emissions compared to the 200 Area facilities. No significant stack releases from 100 Area operations were reported in the documents that evaluated soil sampling and monitoring (DOE/RL-2005-49, *RCBRA Stack Air Emissions Deposition Scoping Document*).

Releases of long-lived radionuclides, including americium-241, cesium-137, iodine-129, strontium-90, plutonium-238, plutonium-239/240, and plutonium-241, from the 200 East and the 200 West Area major stacks, were a very small fraction of the total inventory emitted into the air. A review of dose reconstruction information indicates that most of the total releases of long-lived radionuclides consist of cesium-137 and strontium-90, with a minor contribution of the other radionuclides.

Potential long-term impacts from these emissions within the Hanford Site have been assessed through air and soil sampling conducted as part of the Near Facility Monitoring and SESP programs (PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*). Near-facility ambient air monitoring was conducted from 2007 through 2009 at three locations in the 100-BC area in support of field remediation activities, for gross alpha, gross beta, strontium-90, and plutonium and uranium isotopes. Plutonium-239/240 and uranium isotopes were detected in some air samples; in general, air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than samples collected farther away. However, the reported concentrations were lower than U.S. Environmental Protection Agency (EPA) action levels for compliance with the radionuclide 40 CFR 61, "National Emissions Standard for Hazardous Air Pollutants" (Appendix E, Table 2). EPA action levels in air would result in a dose of 10 mrem/yr under conditions of continuous exposure (PNNL-17603, *Hanford Site Environmental Report for Calendar Year 2007*; PNNL-18427, *Hanford Site Environmental Report for Calendar Year 2008*; PNNL-19455). No SESP air sampling locations are located in nonoperational areas within 100-BC. Three near-facility soil samples were collected from 100-BC in 2008. Analytical results from these samples were reported to be comparable with those observed at other near-facility sampling locations at the Hanford Site (PNNL-18427).

L3.1.4 Overland Flow

Because the Hanford Site sits in a semiarid region, January, March, and December are the only months that have always received measurable precipitation, reported from 1946 through 2004. Normal annual precipitation at the Hanford Site is 17.7 cm (6.98 in.) (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*). In the Hanford semiarid climate, precipitation is balanced by evaporation, transpiration, and vegetative uptake such that substantial overland flow from precipitation is an unlikely occurrence.

A more likely source for overland flow is historical spills or releases from liquid waste disposal facilities during active operational periods. Liquid effluents generated as a direct result of reactor operations consisted primarily of reactor cooling water, fuel storage basin water, and decontamination solutions.

Leaks more likely to have occurred from the liquid waste disposal sites in the 100 Area that resulted in overland flow are described in the report of the 1975 sampling event (UNI-946, *Radiological Characterization of the Retired 100 Areas*). In general, these leaks were infrequent, well-documented, and resulted in localized contamination around the periphery of the disposal sites. The leaks have been characterized historically or as part of the current RI/FS process. The majority of the leaks have been cleaned up and interim closed out in accordance with the interim action RODs. The identification of leaks or spills from waste sites also is incorporated into the procedure for maintaining WIDS in accordance with TPA MP-14 (RL-TPA-90-0001). Based on the available information, overland flows from liquid waste disposal facilities are limited in lateral extent, and unplanned liquid release sites are identified through existing programs such as WIDS. The factors considered in this evaluation indicate that contamination in nonoperational areas through overland transport is unlikely to occur.

L3.1.5 Biointrusion

Biointrusion episodes in 100-BC have not been described in radiological survey reports for the past 3 years. Radiological surveillance monitoring or vegetation sampling conducted as part of the Near-Facility Monitoring Program (PNNL-19455) have not identified contaminated vegetation episodes around the 100-BC Area.

L3.2 Statistical Evaluations

The statistical evaluations provide estimates of the likelihood of finding previously undiscovered waste sites in the NP areas and the potential for exposure to cesium-137 exceeding selected threshold concentrations in surface soils.

L3.2.1 Relative Probability of Missing an Existing Waste Site

Known waste sites have largely been located in proximity to anthropogenic features and relatively particular topographic conditions. For example, most waste sites found to date tended to be close to roads, in low-lying areas such as ditches or ponds, or proximate to operational areas. The spatial distributions of these geographic variables, measured at known WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A statistical relationship was established to rank the likelihood that an available location might contain a previously unknown waste site. Logistic regression was used to develop the statistical relationship between waste site locations and geographic variables.

Factors considered in developing geographic variables expected to predict locations of known waste sites and sources included distance to operational areas; distance to roads, railroad grades, lakes, streams, or utility rights-of-way (e.g., power lines); and topography.

The geographic characteristics of the known waste sites were investigated to determine if their locations exhibited predictable spatial patterns. The purpose of this analysis was to develop a quantitative predictive model describing relationships so that areas within the River Corridor could be prioritized based on the relative probability that a previously unidentified waste site might be present. This analysis does not provide an absolute probability that a waste site exists, but rather provides a relative probability that allows locations to be ranked to identify the more likely location for a waste site—after all, there may be no additional waste sites in the River Corridor that have not been found. The predictive model provides direction to the most likely places for a waste site to occur if indeed one exists.

The predictive model was developed based on a set of known waste site locations obtained from WIDS (referred to as a “training set”). The results of this model were used to predict the relative probability of encountering a potential waste site in areas that may not have been investigated in the field. This provided a ranking of locations within the NP that could then be investigated in the field, compared with previous field or desktop investigation results to determine the potential that additional previously undetected waste sites may remain within the NP. In the River Corridor area, the modeled predictions were compared with information generated from the OSE. The modeled predictions were compared with miscellaneous remediation points and waste site points observed during observations of aerial photography and LiDAR imagery, field walkdowns, and vehicular road surveys conducted as part of the OSE. These comparisons provided independent validation of the predictive model.

The waste site probability map is plotted in Figure L-5 showing the 100-BC area. In the vicinity of 100-BC none of the validation waste site points (locations identified during the OSE and used to validate the predictive model) are located in areas with relative probability less than 5 percent and most are within areas with relative probabilities of 20 percent or greater. This means that in the areas where no waste site points were identified through the OSE process, the probability of an undetected waste site requiring enrollment in the TPA MP-14 process is less than approximately 2 percent.

The relative probability of a waste site is highest within the decision area boundaries and adjacent to smaller local roads. Outside the decision unit boundaries, the relative probabilities are generally less than 2 percent, with the exception of areas that are proximate to smaller roads that could afford easy access for discarding wastes.

All of the River Corridor area, and by extension 100-BC, was investigated through the OSE virtual walkdowns, including investigation of high-resolution aerial photography, LiDAR, and other sources of information available in electronic form. In addition, the areas within the red dashed polygons (see Figure 3-1 in the main text) were also investigated exhaustively through field walkdowns. In 100-BC, the field walkdowns generally captured all areas with 20 percent or greater relative probability of containing a waste site. The field walkdowns provide essentially 100 percent field coverage for identification of potential waste sites. Generally speaking, field walkdowns in 100-BC coincide with the areas identified statistically to be the most likely to contain waste sites; that is, areas close to operational facilities, known waste sites, and secondary roads that could afford easy access for dumping waste.

L3.2.2 Spatial Analysis of Soil Radionuclides and Aerial Surveys

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive radiological aerial surveys. Soil measurements were expressed as activities per unit mass (pCi/g) suitable for estimation of exposure for risk assessment, but provide only limited understanding of the spatial distribution of concentrations. Data obtained from aerial surveys interrogates much larger areas, but are expressed as gross counts for gamma-emitting radionuclides. The aerial survey data were not directly applicable to estimation of potential exposure without calibration to directly measured soil concentrations.

For purposes of the NPE, aerial survey data were calibrated against measured soil cesium-137 activity data. Geostatistical methods were used in a preliminary study to develop a spatially explicit relationship between soil activity measurements and aerial survey gross counts within BCCA. Detailed geostatistical analysis was conducted within the BCCA because high-resolution aerial survey data and relatively high-density soil sampling data were available for this area. The preliminary analysis of the BCCA data was used as a pilot study to support determination to proceed with development of a more extensive sitewide model based on less-resolved, but more laterally extensive aerial surveys of all of the Hanford Site. The results of the sitewide model were used to draw conclusions regarding the distribution of cesium-137 (a contaminant of potential concern related to Hanford Site operations) specific to the NP area.

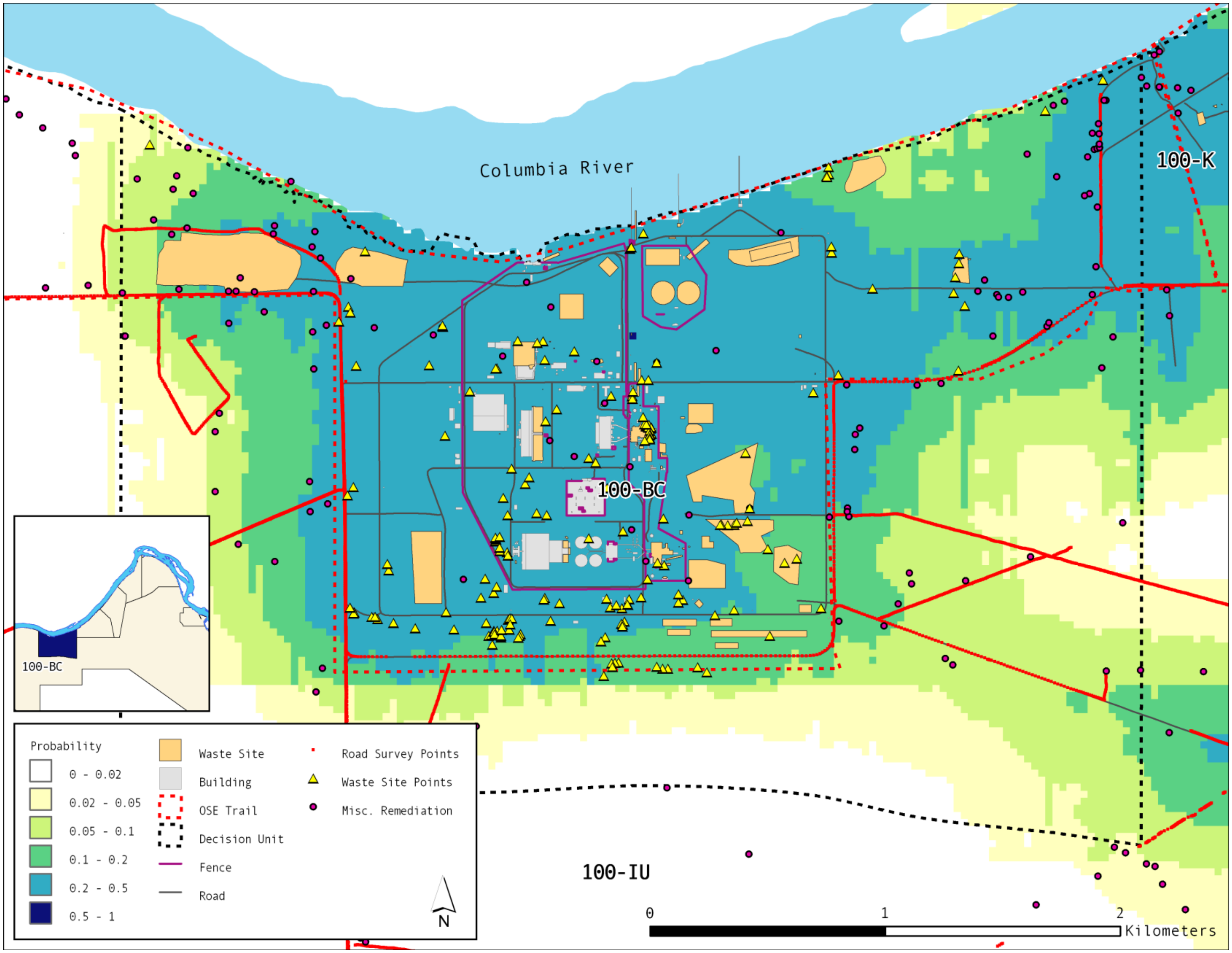

Figure L-5. Relative Probability of Waste Site Locations in the 100-BC Area of the River Corridor

Aerial surveys conducted in 1996 (DOE-0335, *An Aerial Radiological Survey of the Hanford Reservation Richland Washington, Date of Survey: February 29 to March 21, 1996*) and 2009 (SGW-45563, *An Aerial Radiological Survey of the Hanford BC Controlled Area and West Lake Area Survey Data Survey Data – September 22 to 30, 2009*) were combined with ground radiological surveys and soil sampling and analytical data for cesium-137 in the BCCA to establish a relationship to the aerial survey results and measured concentrations in soil. A statistical model of the probability that soil cesium-137 levels exceed selected threshold levels (1.05, 1.5, 3.1, and 6.2 pCi/g) was developed as a function of gross counts of gamma-emitting radionuclides using sitewide aerial survey results. The statistical model was validated against a set of waste sites in the 200-MG-1 OU, where radiological surveys and soil sampling and analysis had been conducted as part of interim remedial actions.

The logistic regression models provide estimates of the probability of exceeding threshold levels, which can be interpreted as estimates of the proportion of an area that would be expected to exceed those levels if one were to sample them. The probability that cesium-137 activities exceed 1.05 pCi/g within 100-BC are shown in Figure L-6. The highest probabilities are focused on the reactor buildings in the south central portion of the area and the 107-C Liquid Waste Disposal trenches and retention basin. North of these areas there is apparent evidence of cesium-137 levels that exceed 1.05 pCi/g with probabilities in excess of 30 percent just north of the fence line. Probabilities closer to the Columbia River are generally less than 20 percent. Because these areas are close to disposal areas and the reactor facilities, it is plausible that these estimates could be a result of elevated soil cesium-137 activities, or they may be related to increased gamma activity from radioactive sources within the operational area. It is anticipated that this uncertainty would be resolved during the RI/FS process associated with confirmation and closure of remedial actions in this area. Other areas outside the fence line at 100-BC indicate that the probability of exceeding 1.05 pCi/g is less than 10 percent. Hanford Site background for cesium-137 is 1.05 pCi/g, which is the 90^{th} percentile of the Hanford background sample data. Because, with the exception of the small area along the north boundary, the probability of exceedance outside the fence line is less than 10 percent, soil cesium-137 levels are at or below Hanford background levels in the NP areas proximate to 100-BC.

L3.3 Orphan Sites Evaluation

The results from historical research, field walkdowns, geographical information system (GIS) mapping, and geophysical surveys for the 100-BC Area are summarized in OSR-2007-0001, *100-BC Area Orphan Sites Evaluation Report*. A field walkdown was conducted over 479 ha (1,185 ac) of 100-BC. Nine orphan sites were identified through the 100-BC evaluation. Subsequent characterization and determination of any remedial actions were addressed as part of the River Corridor Completion Contract (RCCC) scope.

There were 24 miscellaneous restoration items identified during the OSE for 100-BC. These items included abandoned railroad lines, abovegrade utilities, clean surface concrete debris, and abandoned fences that are not otherwise addressed by CERCLA decision documents under the RCCC scope.

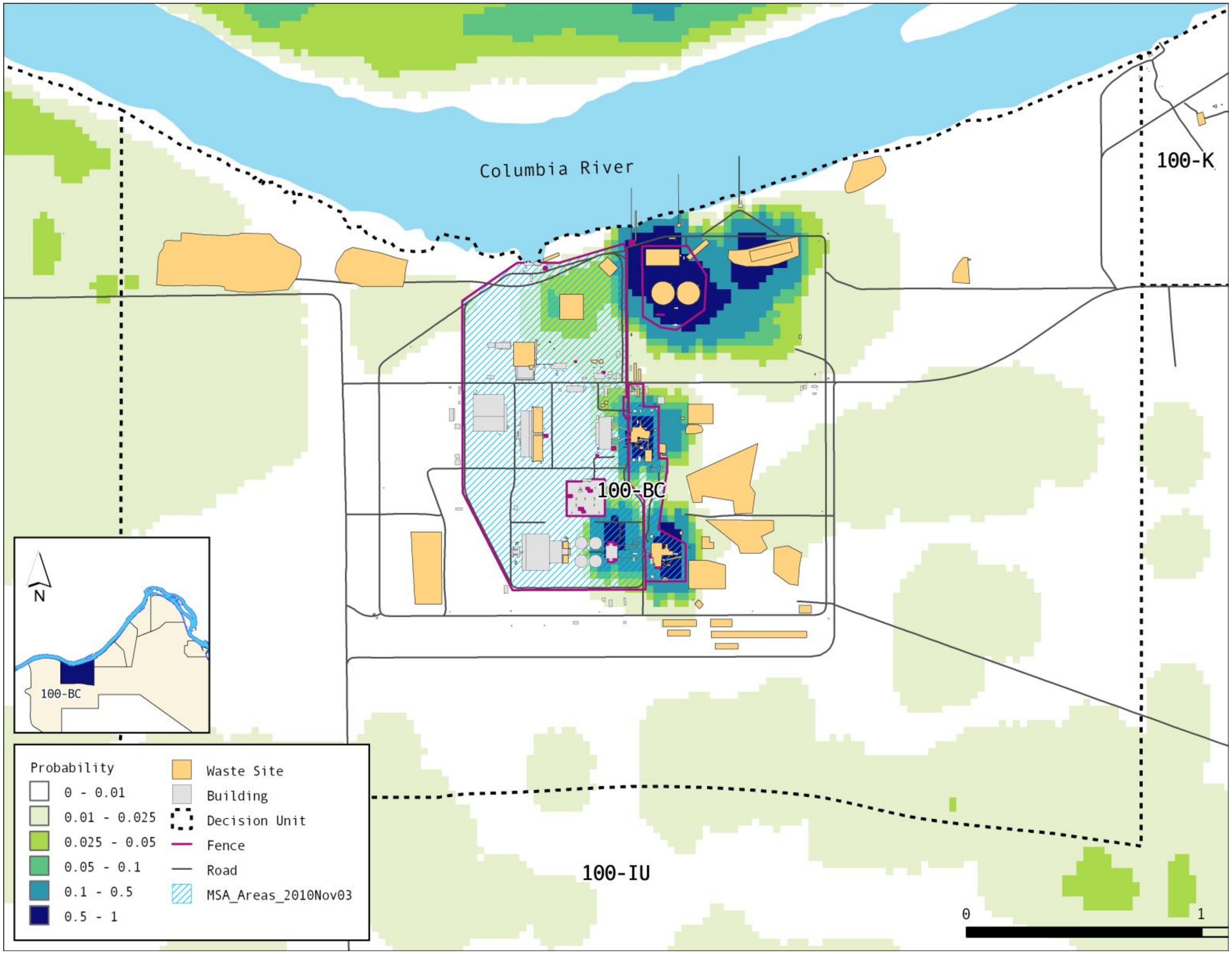

Figure L-6. Modeled Probability that Soil Cesium-137 Exceeds 1.05 pCi/g in the 100-BC Area of the Hanford Site

L4 Conclusions

Multiple lines of evidence were reviewed to evaluate conditions in the 100-BC NP area (and the River Corridor more generally) based on potential release and transport mechanisms. Surveillance and monitoring programs, in combination with the OSE, have comprehensively identified all waste sites within 100-BC. In addition, the surveillance and monitoring programs, in combination with studies conducted as part of the Hanford Environmental Dose Reconstruction Project, have demonstrated that emissions to the air, either from wind-blown dust or from stack emissions, have not affected NP area soils with radionuclides. The surveillance and monitoring programs also have verified that biointrusion has not resulted in a spread of contamination into the NP areas.

Statistical analysis of the geographical distribution of waste sites based on man-made features and topography describes the likely locations of waste sites within 100-BC. The results from this analysis reinforce the findings from the OSE, which has systematically identified the remaining waste sites within 100-BC. Statistical analysis of the distribution of radionuclide concentrations observable from aerial surveys has confirmed that the probability of detecting elevated radionuclide concentrations in NP area soils is very small.

Based on the evaluation of these multiple lines of evidence, the probability of identifying waste sites or contaminant dispersal from Hanford Site operations in 100-BC NP areas is considered negligible.

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